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RESEARCH MEMORANDUM

A TRANSONIC WIND-TUNNEL INVESTIGATION OF THE CHARACTERISTICS OF A TWISTED AND CAMBERED 45° SWEPTBACK WING-FUSELAGE CONFIGURATION

By Daniel E. Harrison

Langley Aeronautical Laboratory
Langley Field, Va.

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RESEARCH MEMORANDUM

A TRANSONIC WIND-TUNNEL INVESTIGATION OF THE CHARACTERISTICS OF A TWISTED AND CAMBERED 45° SWEPTBACK WING-FUSELAGE CONFIGURATION

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SUMMARY

An investigation has been made in the Langley 8-foot transonic tunnel to determine the effects of twist and camber on the aerodynamic characteristics of a sweptback wing-fuselage configuration. The wing had 45° sweepback of the 0.25 chord, an aspect ratio of 4, a taper ratio of 0.6, and NACA 65A-series airfoil sections with 6-percent-thickness distribution parallel to the plane of symmetry. The twist and camber used was designed to obtain a uniform load distribution at a Mach number of 1.2 and a lift coefficient of 0.4.

Comparisons of the results with those obtained for a plane-wing—fuselage combination indicated that the twist and camber used increased the maximum lift-drag ratios of the wing-fuselage configuration at test Mach numbers up to 0.84 and above 0.99, but decreased the ratios between these Mach numbers. The twist and camber, however, produced significant improvements throughout the Mach number range in the lift-drag ratio values at the higher lift coefficients which are of particular interest in the climb or maneuver conditions of flight. In addition, substantial increases in the lift-coefficient values at which the unstable break in the pitching-moment curves occurred were obtained throughout the Mach number range. At a Mach number of 1.00, the lift coefficient at which the unstable break in the pitching-moment curve occurred was delayed approximately 0.2 by the use of twist and camber. The breaks at the upper limit of the linear portion of the lift curves also occurred at higher lift-coefficient values for the twisted and cambered wing than for the plane wing.

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INTRODUCTION

Previous investigations have indicated that the use of twist and camber improves the characteristics of sweptback wings for moderate and high lift coefficients at subsonic and supersonic speeds (refs. 1 and 2). The use of twist and camber also would be expected to improve the characteristics of sweptback wings in the transonic speed range. In order to provide an indication of the effects of twist and camber in the transonic Mach number range, a 45° sweptback wing, twisted and cambered to obtain a uniform load distribution at a Mach number of 1.2 and a lift coefficient of 0.4, has been tested in the Langley 8-foot transonic tunnel. The relative high lift coefficient, 0.4, was chosen to improve the characteristics of the wing in the maneuver as well as the cruise conditions of flight. The wing was tested with a high-fineness-ratio fuselage through a continuous Mach number range from 0.80 to 1.10 and at angles of attack from about -6° to 16°. The results are compared herein with the results for a comparable plane-wing—fuselage configuration (ref. 3).

SYMBOLS

b	wing span, in.
C_D	drag coefficient, D/qS
C_L	lift coefficient, L/qS
C_m	pitching-moment coefficient, $M_{\bar{c}/4}/qS\bar{c}$
$\bar{c}$	mean aerodynamic chord of wing, in.
c	local wing chord parallel to plane of symmetry, ft
D	drag, lb
L	lift, lb
$(L/D)_{max}$	maximum lift-drag ratio
M	Mach number
$M_{\bar{c}/4}$	pitching moment of aerodynamic forces about lateral axis which passes through 25-percent point of mean aerodynamic chord of wing, in.-lb

P_b base pressure coefficient, $\frac{p_b - p_o}{q}$

p_o free-stream static pressure, lb/sq ft

p_b static pressure at model base, lb/sq ft

q dynamic pressure, $\rho V^2/2$, lb/sq ft

R Reynolds number based on $\bar{c}$

S wing area, sq ft

V velocity, ft/sec

α angle of attack of body center line, deg

ρ air density, slugs/cu ft

x distance measured from leading edge of wing along local chord, in.

y spanwise distance from plane of symmetry, in.

z camber, in.

ϵ angle of wing twist measured relative to fuselage reference line (fig. 1), deg

APPARATUS AND METHODS

Tunnel

The tests were conducted in the Langley 8-foot transonic tunnel which is a dodecagonal, slotted-throat, single-return type of wind tunnel. The use of the longitudinal slots along the test section permitted the testing of the models through the speed of sound without the usual choking effects found in the conventional closed-throat type of tunnel. A complete description of the Langley 8-foot transonic tunnel can be found in reference 4.

Configuration

Except for twist and camber, the wing investigated was identical to the plane wing of reference 3. The wing has 45° sweepback of the

0.25-chord line, an aspect ratio of 4, a taper ratio of 0.6, and NACA 65A-series airfoil sections with 6-percent-thickness distribution parallel to the plane of symmetry. Steel was used in the construction of the wing. A plan-form drawing of the wing-fuselage configuration is presented in figure 1.

The twist and camber used were determined by the method presented in reference 5. The wing was designed to obtain a uniform load distribution at a lift coefficient of 0.4 and a Mach number of 1.2. The resulting twist and camber values are presented in figure 2. As shown in this figure, the angle of twist varied from 4.5° at the root to -0.2° (washout) at the tip. Twist was measured from the longitudinal axis of the fuselage. The chordwise location of the maximum camber was 40 percent of the streamwise chord throughout the span.

A detailed description of the high-fineness-ratio fuselage tested with the twisted and cambered wing is given in reference 6.

Measurements and Accuracy

Lift, drag, and pitching moment were measured by an electrical strain-gage balance. The accuracy of the resulting coefficients is as follows:

C_L	±0.010
C_D	±0.001
C_m	±0.002

The base-pressure coefficients were determined by means of two static orifices located on the sides of the sting support in the plane of the model base. The drag data have been adjusted for base pressures such that the drag corresponds to conditions where the body base pressure is equal to the free-stream static pressure. No corrections have been made to the base pressures for sting interference effects (ref. 6).

Local deviations from the average free-stream Mach number in the region of the model were no larger than 0.003 at subsonic speeds. With increases in Mach number above 1.00, the deviations increased but did not exceed 0.010 at a Mach number of 1.13.

A Selsyn unit, located at the pivot point of the model support sting, was used to measure the angle of attack. A correction, due to elasticity of the sting support, was applied to the angle-of-attack measurements. The accuracy of the angle-of-attack measurements was within ±0.20°.

Boundary interference effects consisted of shocks and expansions from the model which were reflected back to the surface of the model by the test-section boundary at Mach numbers above 1.00. These disturbances pass downstream of the model at a Mach number of approximately 1.10. The reflected shocks reduced the drag coefficient at low angles of attack as much as 0.002 at a Mach number of 1.07; however, the disturbances had negligible effect on the lift-coefficient values throughout the Mach number range (ref. 6). No corrections have been made to the drag data for the boundary interference effects.

RESULTS

The basic aerodynamic data (angle of attack, drag coefficient and pitching-moment coefficient against lift coefficient) are presented in figure 3. Comparisons of the basic data for the twisted and cambered wing-fuselage configuration and the plane-wing—fuselage configuration are shown in figure 4. The base pressure coefficients for the two configurations are shown in figure 5. The effects of twist and camber on the variation of drag due to lift with lift coefficient are presented in figure 6. Variations of maximum lift-drag ratios with Mach number for the comparable configurations are shown in figure 7. Also shown in figure 7 are the lift coefficients at which the maximum lift-drag ratios occurred. The curves of lift-drag ratio against Mach number are shown in figure 8 for several lift coefficients.

In order to facilitate presentation of the data, staggered scales have been used in many of the figures and care should be taken in identifying the zero axes for each curve. All references to wings in the following discussion refer to data presented for wing-fuselage configurations. The Reynolds number based on the wing mean aerodynamic chord varied from 1.91×10^6 to 1.99×10^6.

DISCUSSION

Lift Characteristics

The angle of attack of the wing-fuselage configuration for zero lift (fig. 4) was decreased approximately 3° throughout the Mach number range by twisting and cambering the wing. Up to 6° angle of attack, the slopes of the lift curves for the two configurations were nearly equal. The breaks at the upper limit of the linear portion of the lift curves occurred at higher lift-coefficient values for the twisted and cambered wing than for the plane wing. Generally, these breaks occurred at lift-coefficient values approximately equal to the values at which the unstable break in the pitching-moment curves occurred.

Drag Characteristics

At zero lift, the drag values of the twisted and cambered wing were appreciably higher than the drag values of the plane wing (fig. 4). Above a lift coefficient of 0.4 and for all test Mach numbers, however, the twist and camber reduced the drag-coefficient values for a given lift coefficient. Thus, the drag due to lift values was greatly reduced by the use of twist and camber in the moderate and high lift-coefficient range (fig. 6). The greater reductions occurred in the subsonic Mach number range. At a lift coefficient of 0.6, the drag due to lift value was reduced approximately 33 percent for a Mach number of 0.6 as compared to 13 percent for a Mach number of 1.2. Also shown in figure 6 are the values for the theoretical drag due to lift for subsonic Mach numbers and for Mach number 1.2. The theoretical value for a Mach number of 1.2 was obtained from reference 5.

The maximum lift-drag-ratio values presented in figure 7 indicated that the use of this particular twist and camber increased the $(L/D)_{max}$ values slightly at Mach numbers up to 0.84 and above 0.99 but reduced the ratios between these Mach numbers. This reduction may be due to increases in wing-fuselage interference associated with the twist and camber. The results of reference 7 indicated that a strong shock is produced behind the trailing edge of the inboard sections of the wing which travels outwardly across the outboard sections of the wing. This shock may have produced greater amounts of separation on the outboard region of the cambered and twisted wing than on the plane wing. The maximum reduction was approximately 12 percent at a Mach number of 0.92. Also shown in figure 7 are the maximum lift-drag-ratio values obtained at subsonic speeds for the plane and twisted and cambered wing-fuselage combinations of reference 1. The wings had 45° sweepback of the 0.25-chord line, an aspect ratio of 5, and a taper ratio of 0.565. The results of these tests also indicated that the use of twist and camber increased the maximum lift-drag ratio values at lower subsonic speeds but decreased them at higher subsonic speeds. The generally greater $(L/D)_{max}$ values obtained for these configurations in comparison with those obtained from the present investigation are due primarily to the large differences in the ratios of the fuselage cross-sectional area to the wing area. The relative size of the fuselage was approximately 90 percent higher for the present investigation than that for the investigation of reference 1.

The lift-drag ratios are presented in figure 8 as a function of Mach number for several lift-coefficient values. It is shown here that significant gains in lift-drag-ratio values were obtained by the use of twist and camber above a lift coefficient of 0.4 throughout the Mach number range. These gains are of particular importance for the climb and maneuver conditions of flight. At a lift coefficient of 0.6 and a Mach number of 0.85, the lift-drag ratio was increased approximately 40 percent.

Pitching-Moment Characteristics

The pitching-moment coefficients for given lift coefficients were made more negative by the use of twist and camber (fig. 4). This shift was due primarily to the fact that lift produced by this particular twist and camber is centered farther rearward than the same lift caused by angle of attack. Also, the changes in pitching-moment-coefficient values were due to the lower angle of attack of the fuselage for a given lift coefficient. The angle of attack of the fuselage was 1.6° less than the angle of the mean aerodynamic chord. Throughout the Mach number range, the unstable break in the pitching-moment curves occurred at higher lift-coefficient values for the twisted and cambered wing than for the plane wing. The increases in lift-coefficient values became larger with increasing Mach number. At a Mach number of 1.00, the lift coefficient at which the unstable break in the pitching-moment curve occurred was delayed approximately 0.2 by the use of twist and camber. The delays in the occurrence of the unstable breaks are of particular importance to the pilot who is flying his aircraft in a climb or maneuver condition. Above a Mach number of 0.95, these delays are approximately as large as those obtained to date by any other means.

CONCLUSIONS

The results of an investigation of the effects of twist and camber on the aerodynamic characteristics of a 45° sweptback wing-fuselage indicate the following conclusions:

1. The twist and camber used in this investigation increased the maximum lift-drag ratios of the wing-fuselage configuration at test Mach numbers up to 0.84 and above 0.99 but reduced the $(L/D)_{max}$ values between these Mach numbers. The twist and camber, however, produced significant improvements throughout the Mach number range in the lift-drag ratio values at the higher lift coefficients which are of particular interest in the climb or maneuver conditions of flight.

2. Substantial increases in the lift-coefficient values at which the unstable breaks in the pitching-moment curves occurred were effected by the use of this particular twist and camber.

3. The breaks at the upper limit of the linear portion of the lift curves occurred at higher lift coefficient values for the twisted and cambered wing than for the plane wing.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va.

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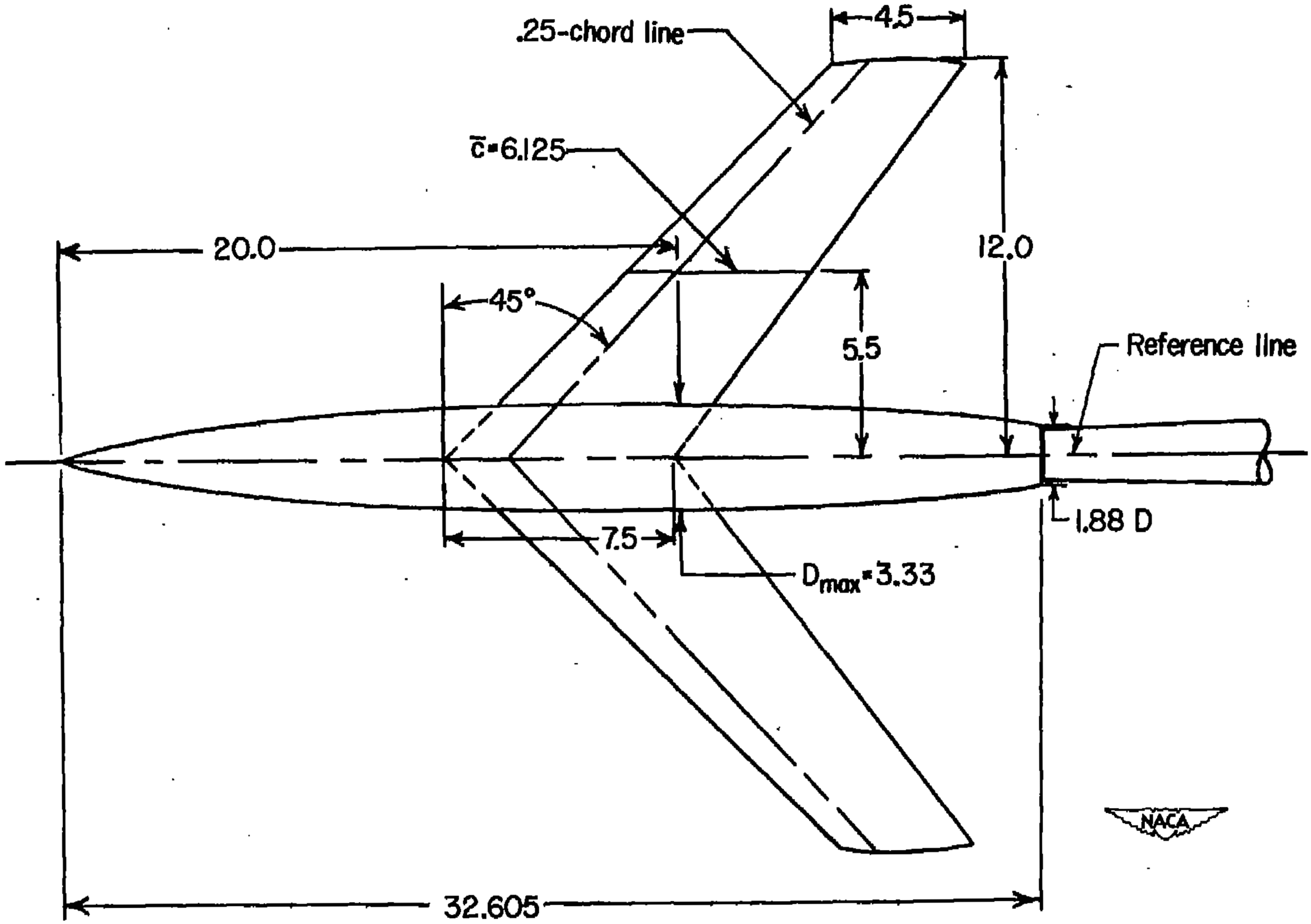


Figure 1.- Wing-fuselage configuration. All dimensions are in inches.

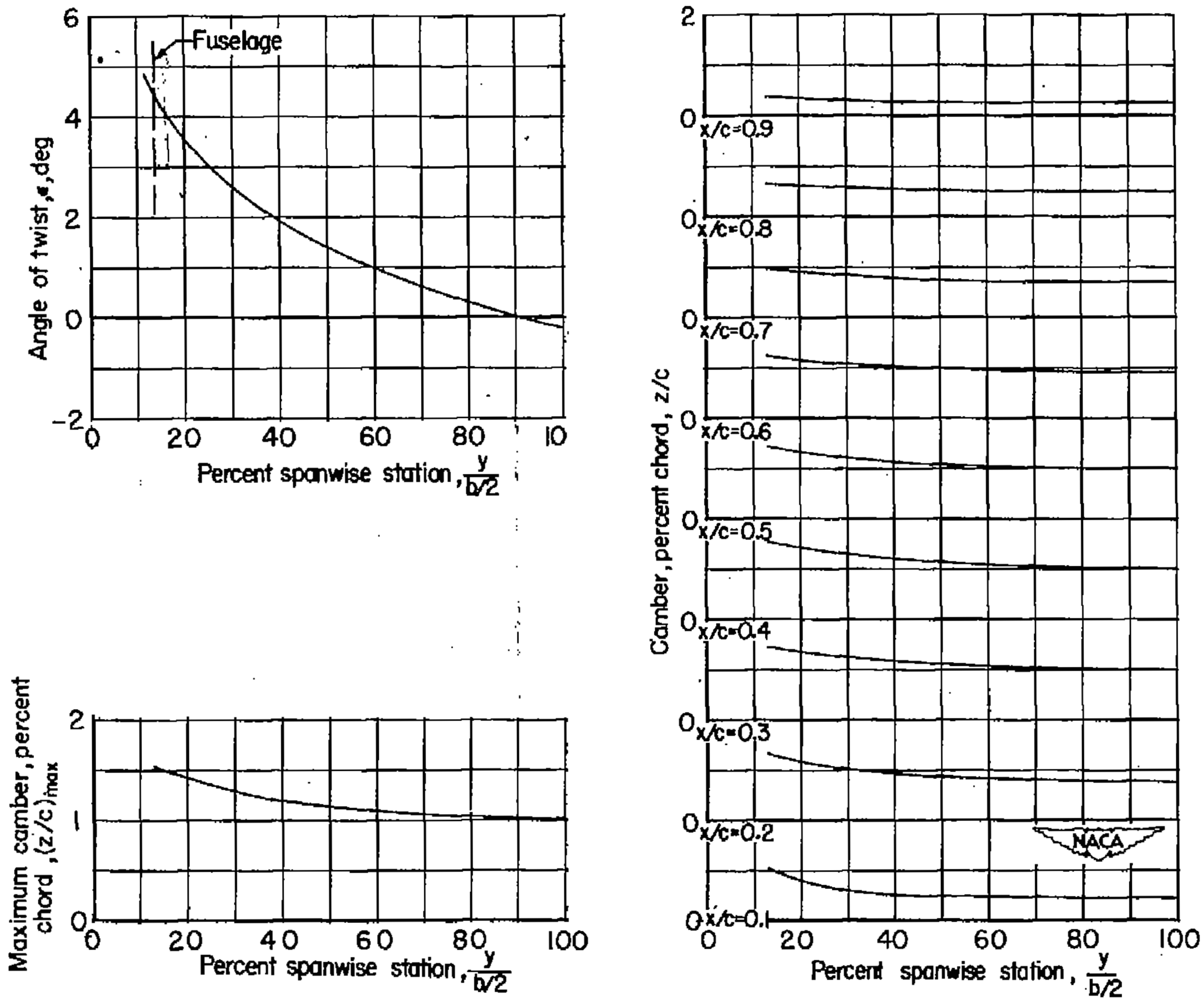
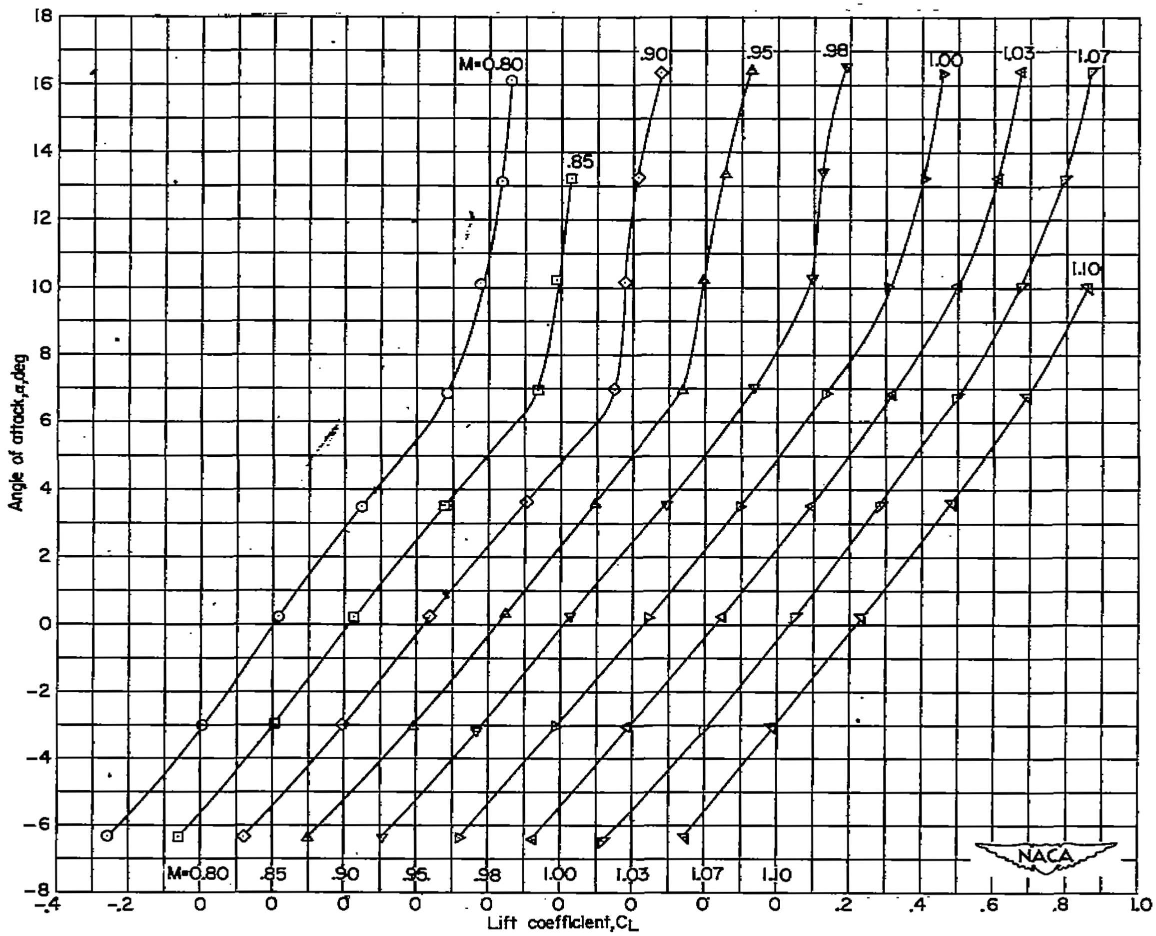
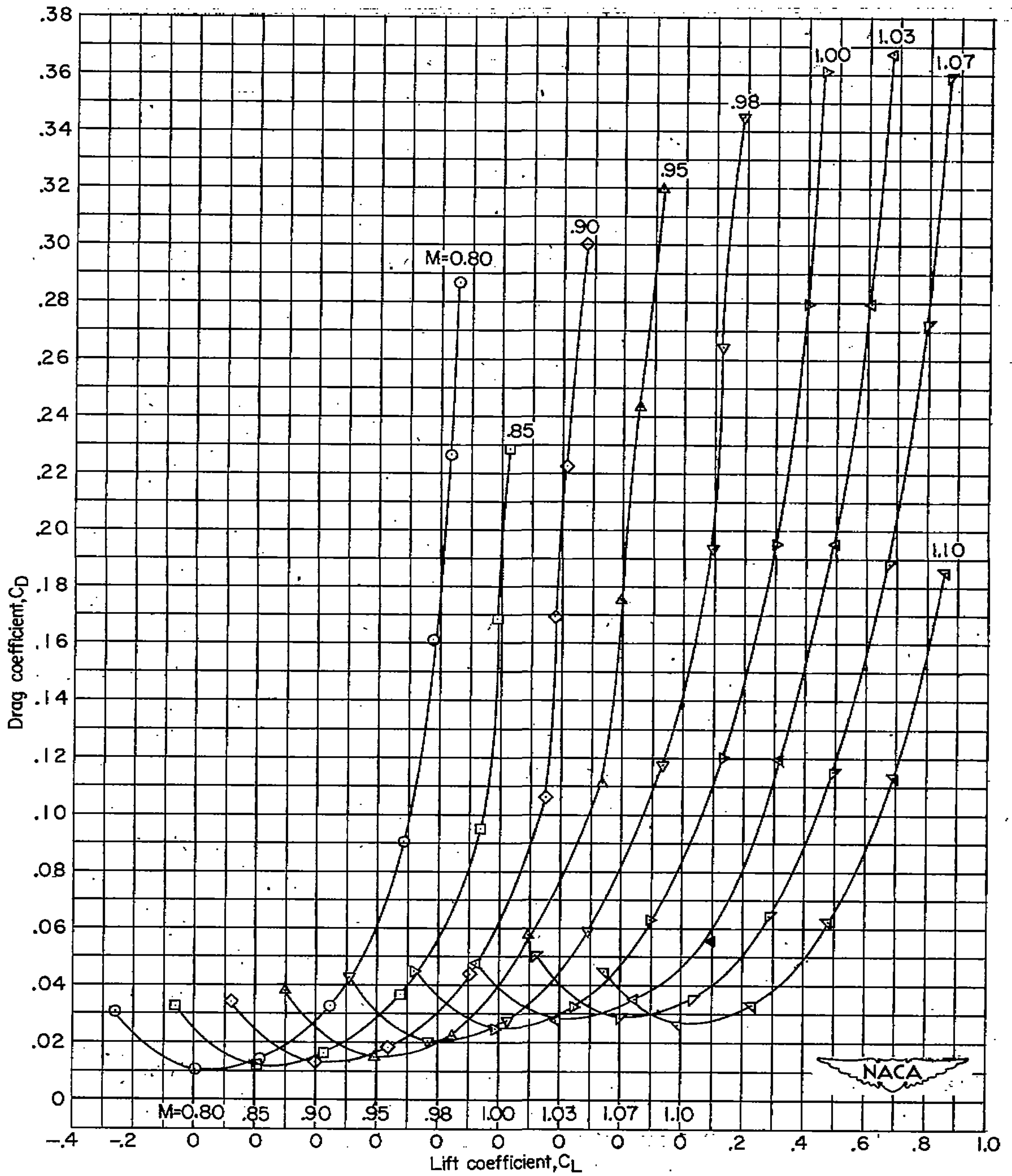


Figure 2.- Spanwise variation of the twist and camber of the twisted and cambered wing.



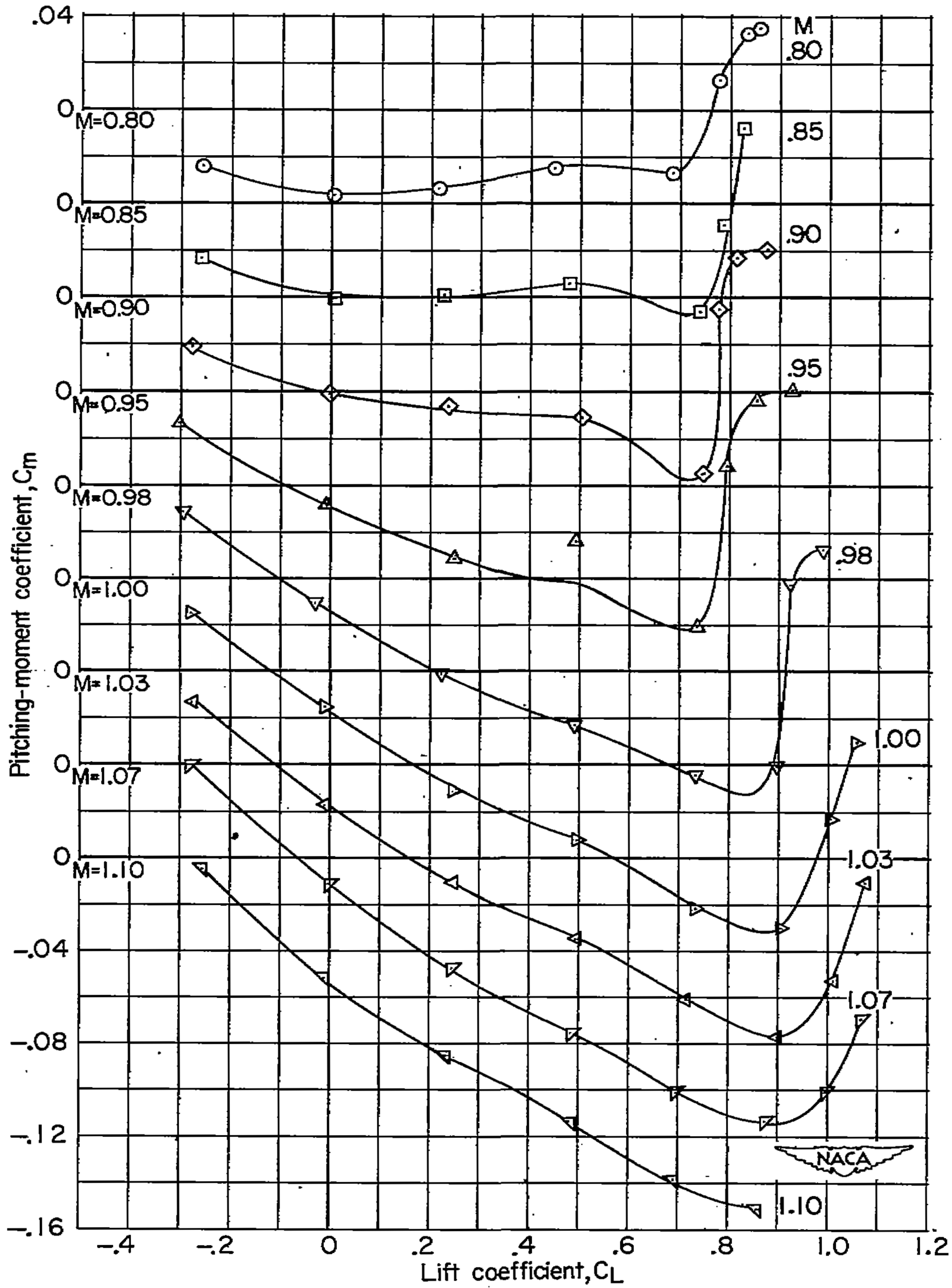
(a) Angle of attack.

Figure 3.- Variation with lift coefficient of the aerodynamic characteristics for the twisted and cambered wing-fuselage configuration.



(b) Drag coefficient.

Figure 3.- Continued.



(c) Pitching-moment coefficient.

Figure 3.- Concluded.

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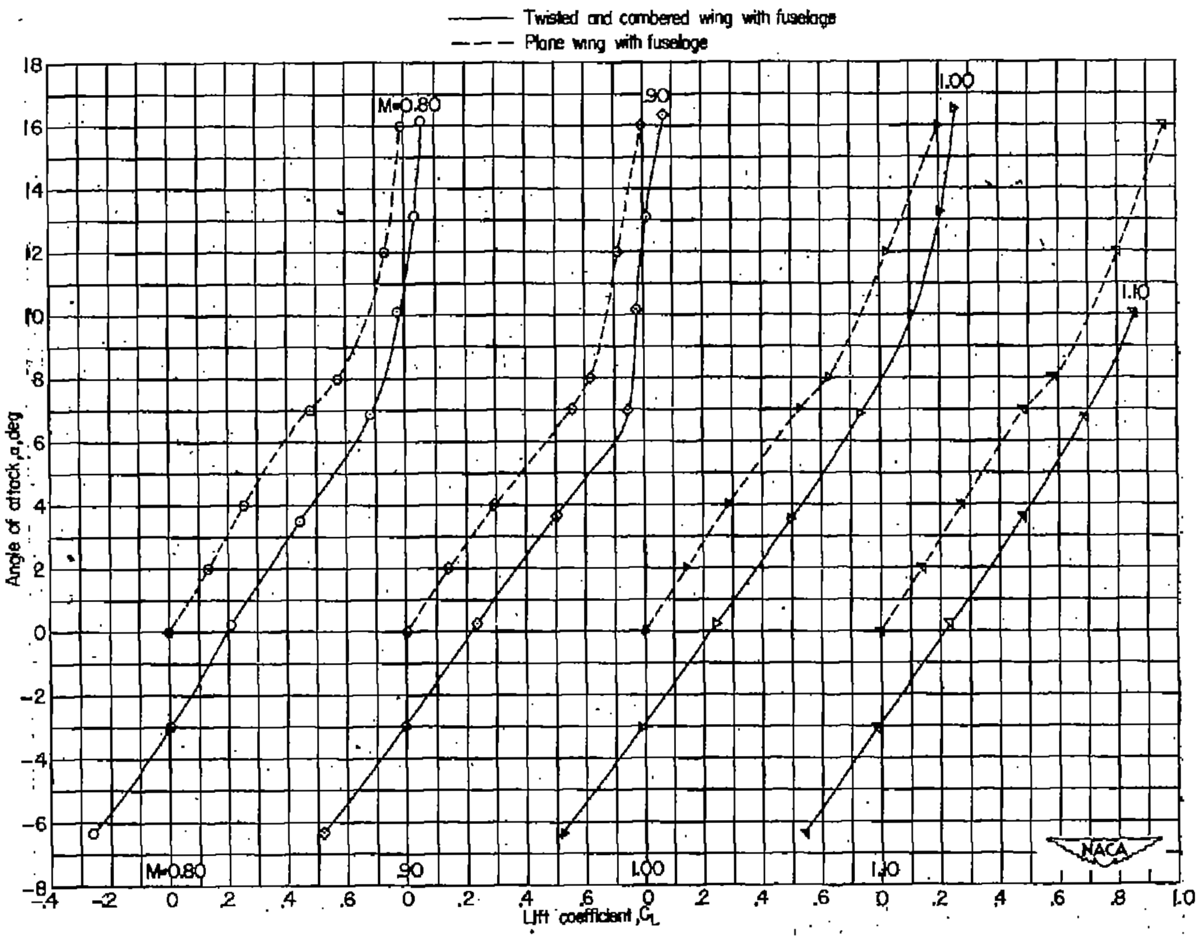

(a) Angle of attack.

Figure 4.- A comparison of the variations with lift coefficient of the aerodynamic characteristics for the twisted and cambered wing-fuselage configuration and the plane-wing—fuselage configuration.

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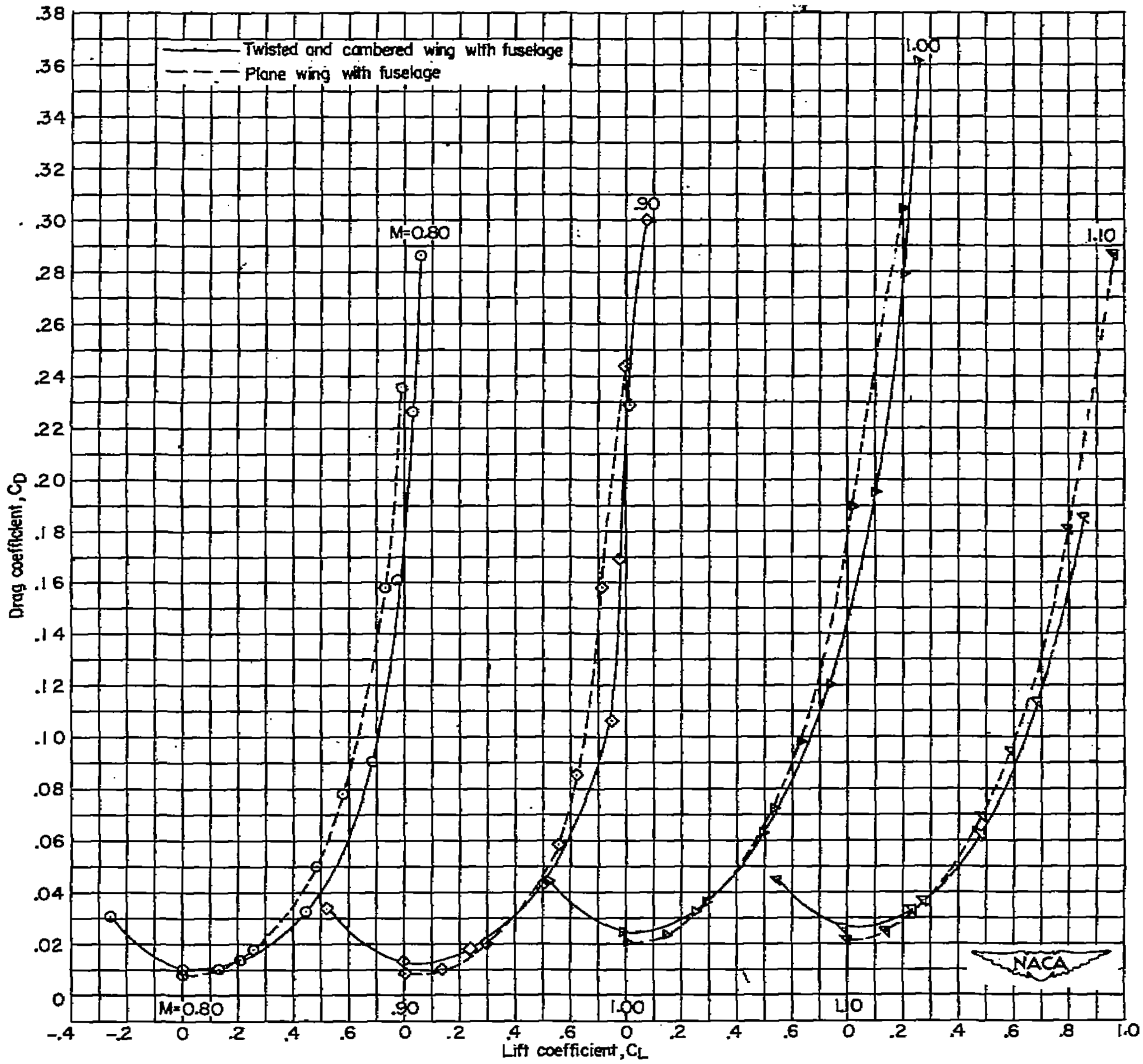
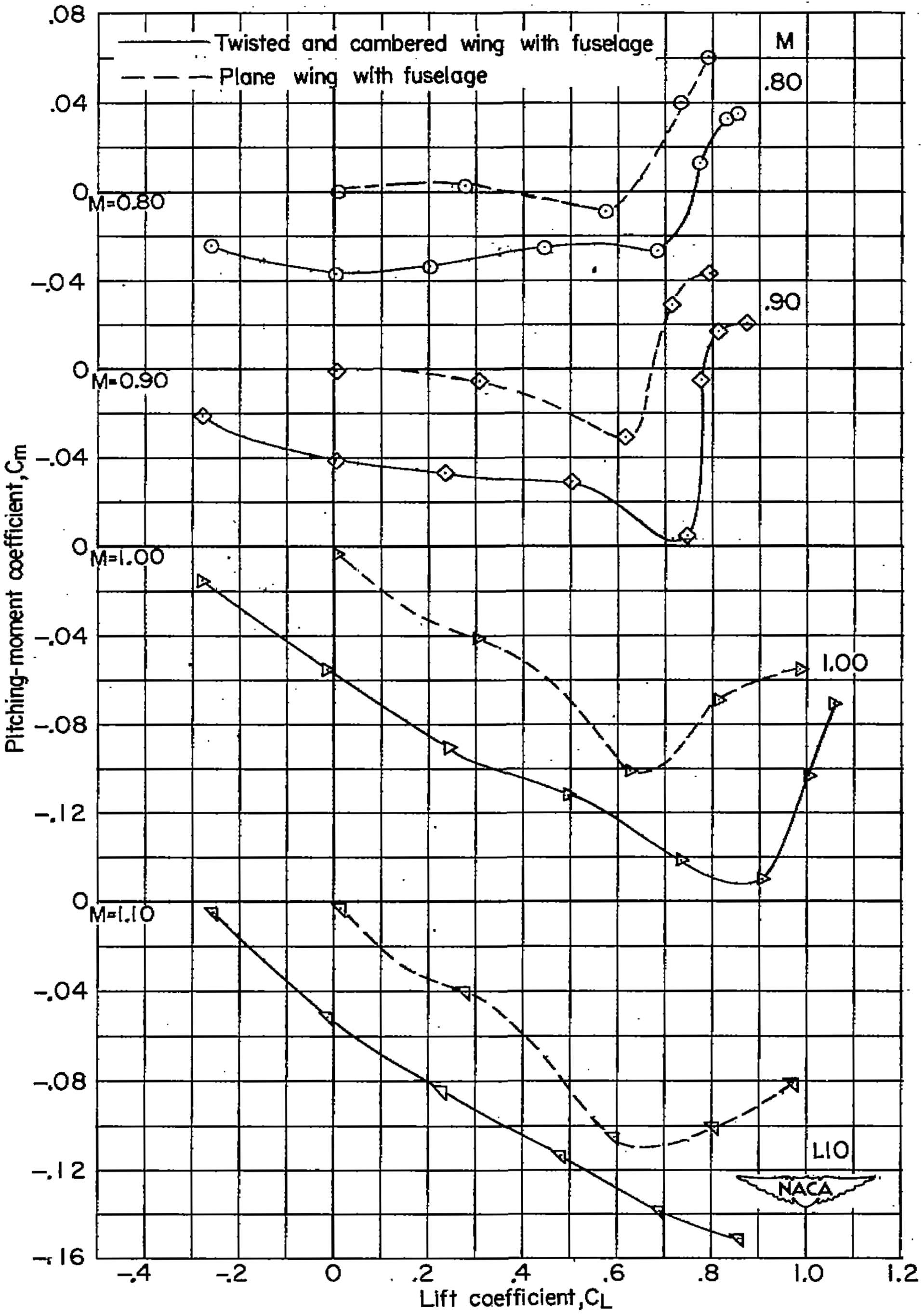


(b) Drag coefficient.

Figure 4.- Continued.



(c) Pitching-moment coefficient.

Figure 4.- Concluded.

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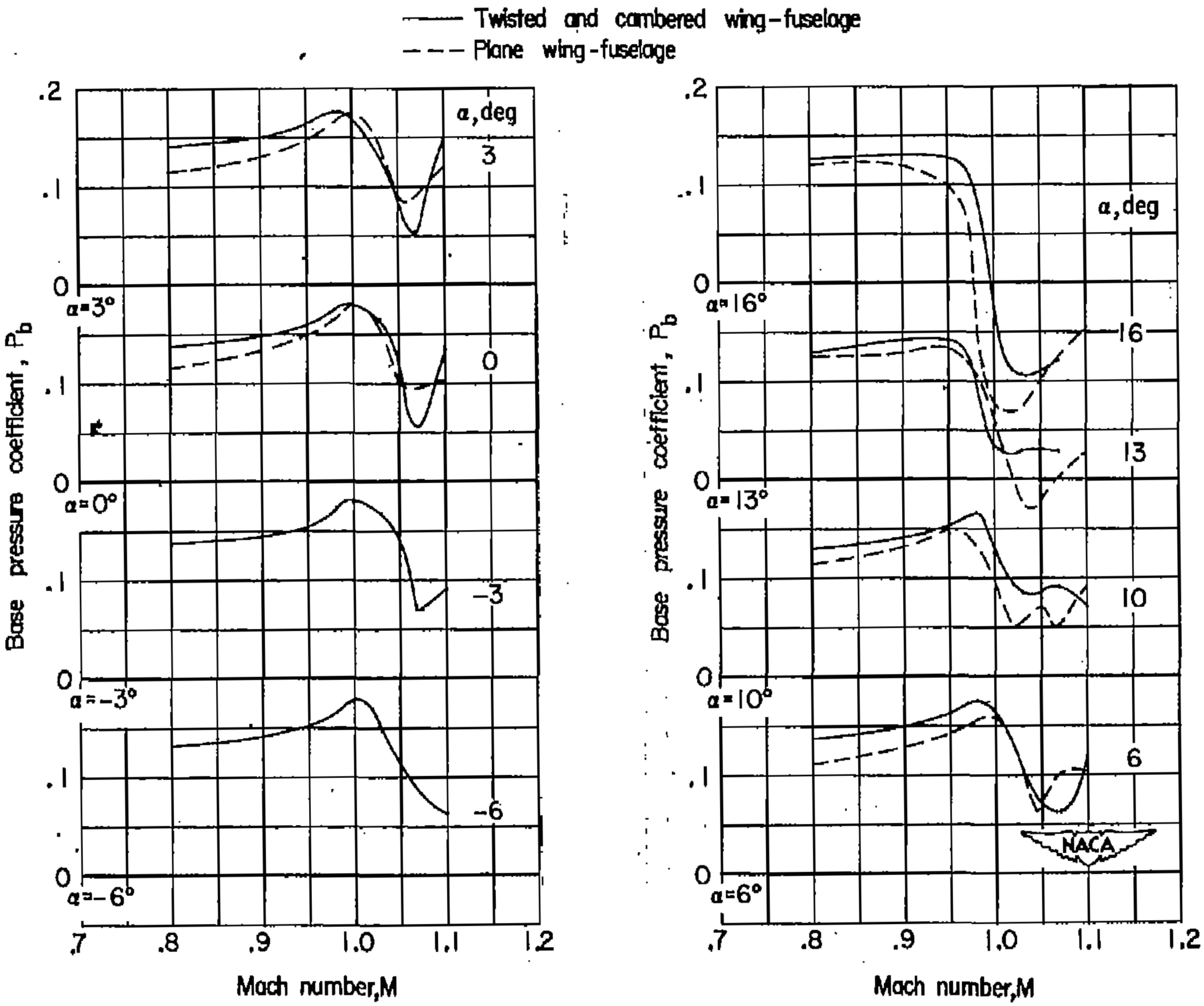

Figure 5.- Variation with Mach number of the base pressure coefficients for the twisted and cambered wing-fuselage and the plane-wing—fuselage configuration.

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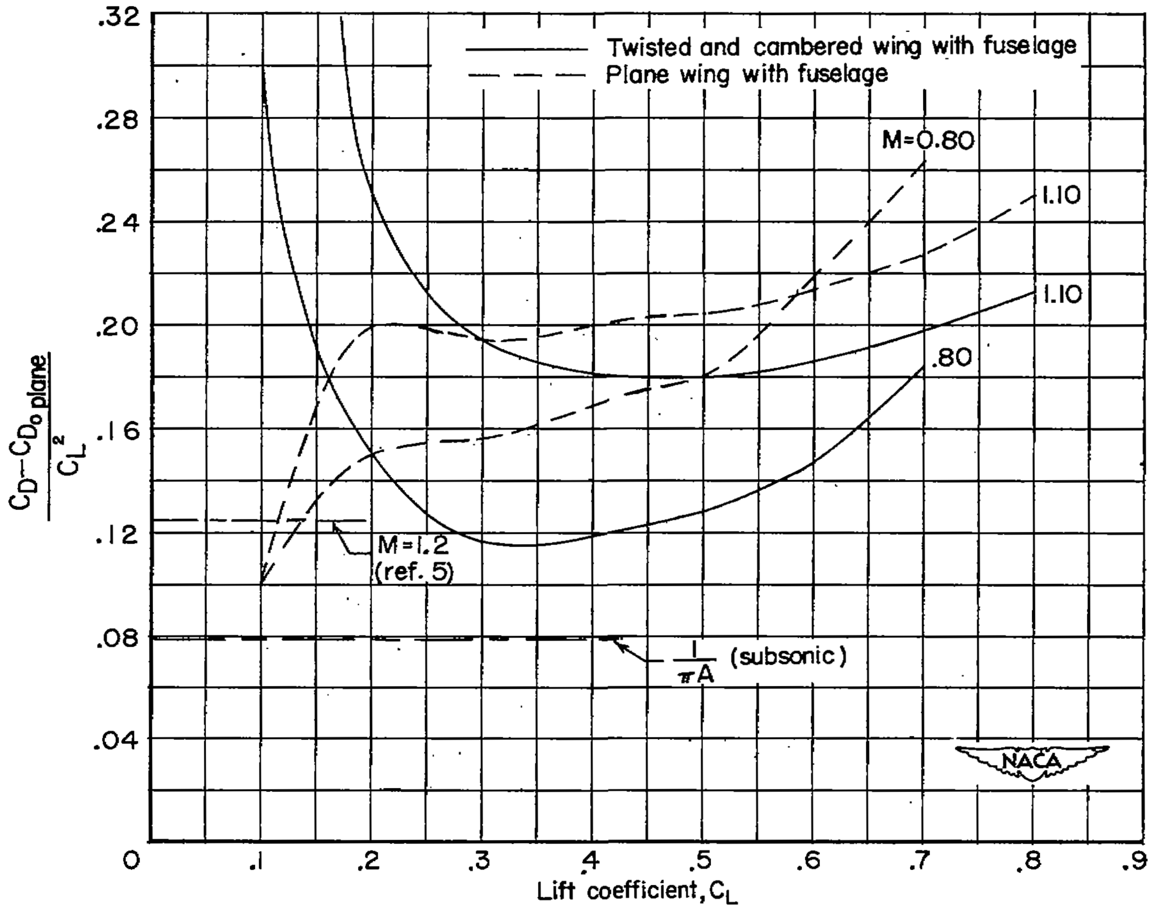

Figure 6.- Effect of twist and camber on the variation of drag due to lift with lift coefficient for the wing-fuselage configuration.

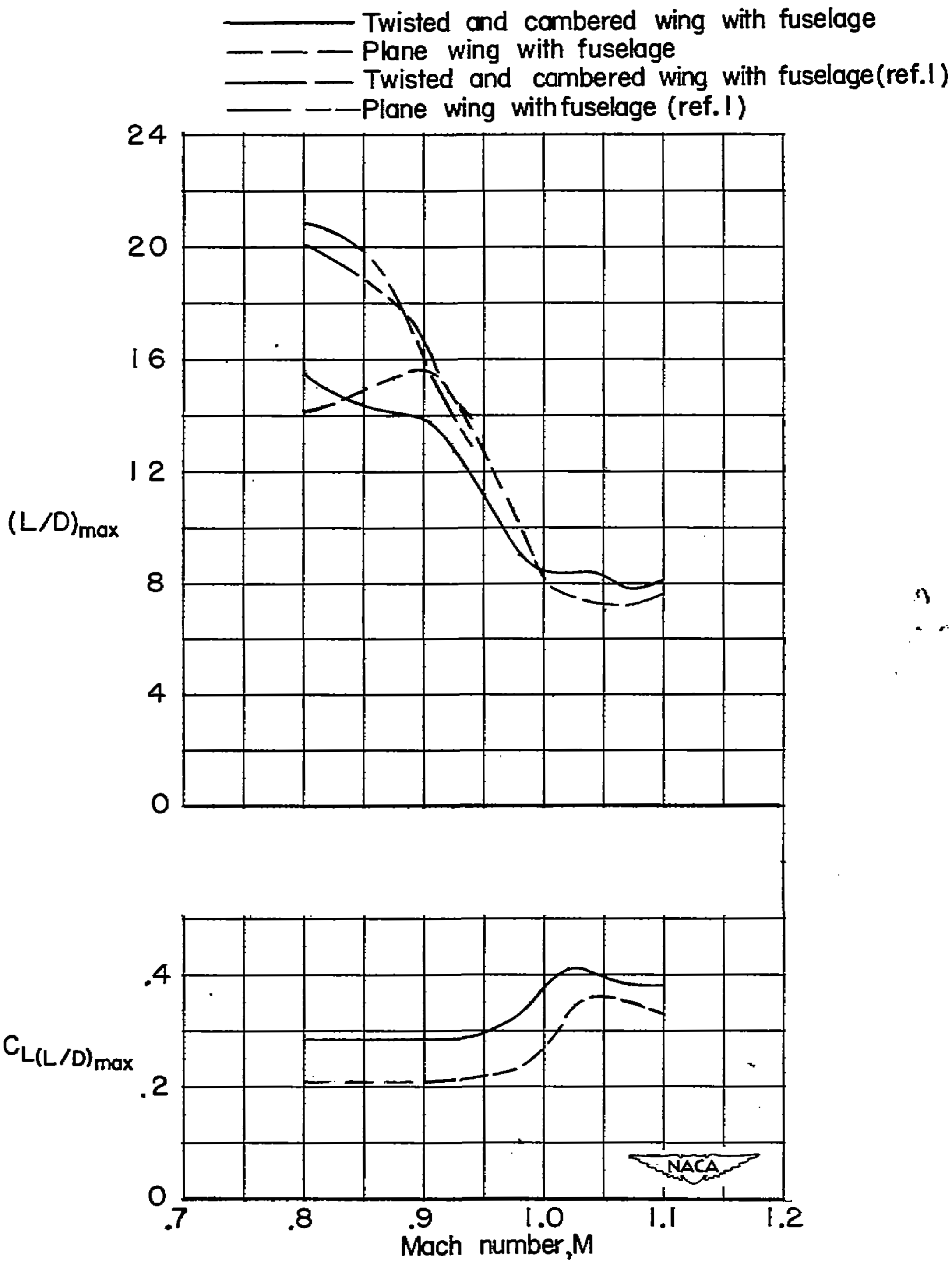

Figure 7.- The effects of twist and camber on the variation of maximum lift-drag ratios with Mach number for the wing-fuselage combination.

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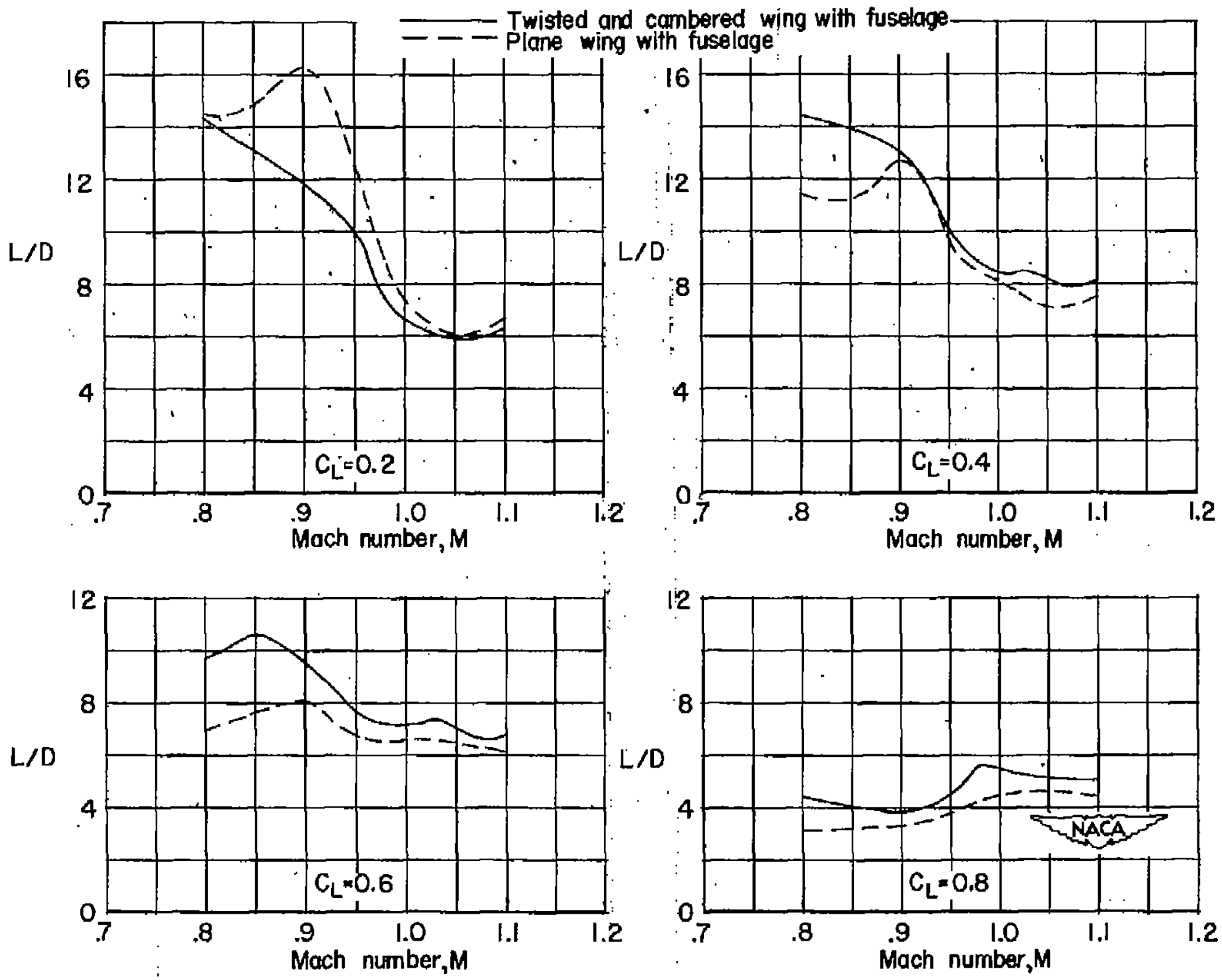

Figure 8.- The effects of twist and camber on the variation of lift-drag ratio with Mach number for the wing-fuselage combination at several lift coefficients.

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